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(SEE PAGE 99)

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Genetics of Cucurbits

VOLUME 35 APRIL, 1944 NUMBER 4

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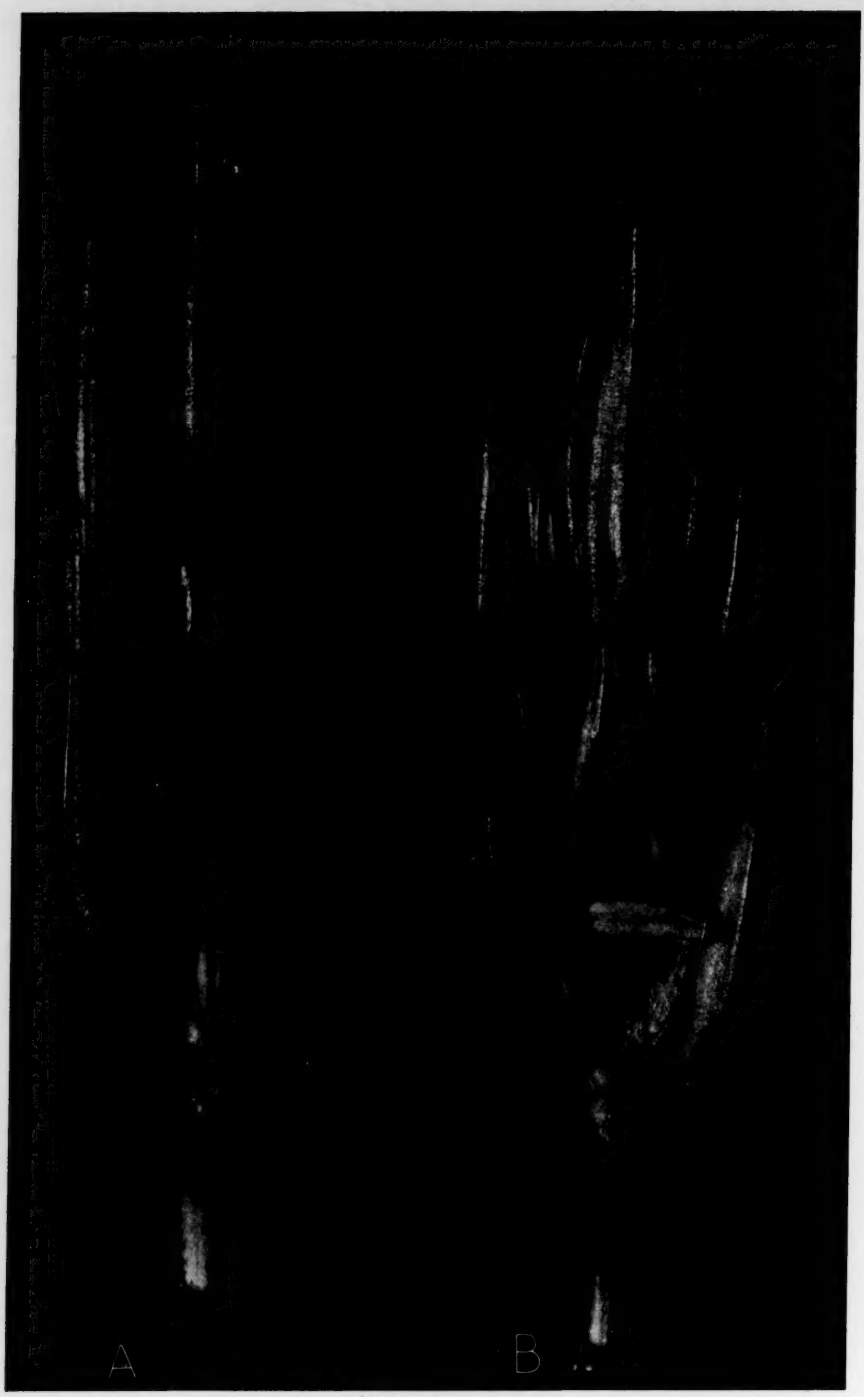

BARLEY FLOWERS

Figure 1

Portions of the spike of six-rowed barley showing the groups of three flowers at a node, seven times natural size. The glumes and the lemmas have been removed from the middle spikelets to show the floral organs against the background of the palet. In (*A*) the flower is slightly immature, with the unbroken anthers still in place. The lodicules, still small, hide the base of the ovule. In (*B*) the flower has been pollinated. Note the swollen lodicules at base, the burst anthers pendant on their elongated filaments, and the wide-spreading, two-branched plumose stigma. (See Figure 5 for details.)

SOME NOTES ON TECHNIQUE IN BARLEY BREEDING

MERRITT N. POPE*

SPECIES of cultivated barley have retained their essential characteristics under the protection of man since the dawn of history. A dense six-rowed barley very similar to the variety "Winter Club" has been found in the prehistoric lake dwellings of Europe. Samples in the collection of the Division of Cereal Crops and Diseases from Egyptian excavations and black with age, are recognizable as types and, in appearance as varieties even, today being grown in North Africa (Figure 2). These arresting evidences of the antiquity of barley, a crop plant specialized for high endosperm content and dependent upon man for a continued existence, demand an even longer prehistoric period of evolution from its hypothetical ancestors. These ancient efforts in plant improvement may have been unintentional, and accomplished through natural selection and survival of the fittest for cultivation. If the improvement was intentional, the evolution was probably considerably faster. In the latter case, the prehistoric "plant breeders" must have been endowed with keen powers of observation and quite remarkable imagination and judgment. Merely to domesticate a wild plant capable of becoming a cereal must rank in importance and creative imagination with the invention of the bow and arrow and the wheel. This prehistoric improvement of barley must have taken the form, first of the introduction of the crop into lands near dwellings and of transportation of seed along with the household effects when migration occurred. The fact that barley is largely self-fertilized makes it a relatively easy crop to maintain. This probably is an important factor in its adoption very early in man's agricultural history. The intentional preservation of the seed of superior plants would naturally have come later still. This stage would have been reached by Greek and Roman times. Hybridization as a source of superior variants probably was not attempted until early in the nineteenth century.

The earliest recorded barley hybrid produced in America was made in 1879 or 1880 by F. H. Horsford of Charlotte, Vermont. This was the first real contribution to barley breeding in the United States. Horsford crossed the hooded naked variety "Nepal" upon an awned hulled sort and obtained the hooded hulled variety still called by his name. During the next quarter of a century, Saunders and Zavitz in Canada, and R. A. Moore and Willet M. Hays in the United States were making notable advances in barley breeding in America.

As can be seen, the modern barley breeders' methods of improving this ancient crop are very young. The early selections and introductions of exotic varieties were effective in improving crops, but except for occasional mutations the types were limited to those forms already present, and early hybridizations were largely "shots in the dark." Since the rediscovery of Mendel's law in 1900, the "art" of plant breeding has become a science as well, and a host of workers has obtained tangible and worthwhile results from hybridization. Now, with a vast number of distinct forms introduced from all parts of the world, and available to any breeder upon request, a variety can be made to order. With self-pollinated crops such as most of the small grains, progress is rapid. There is no preliminary selfing to be

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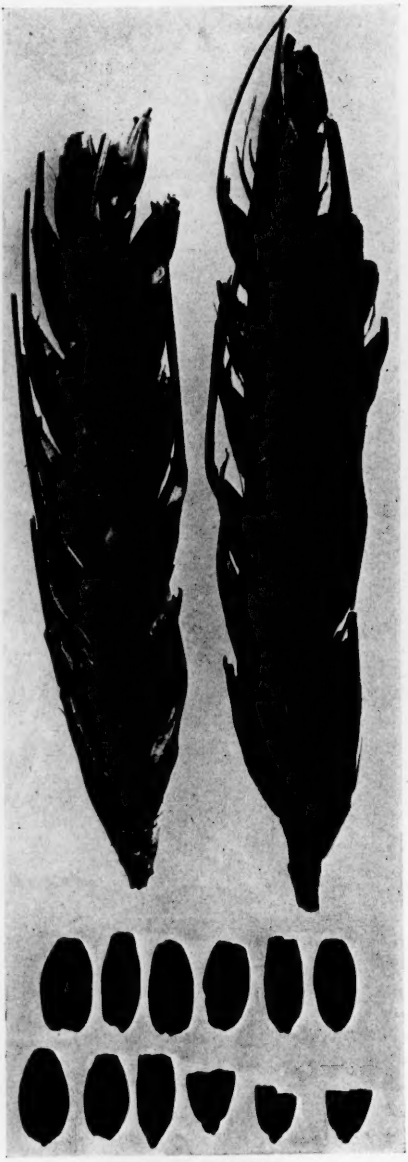
done to obtain uniform material, and there is no need of protecting later generations from foreign pollen. When a valuable variant appears, it is almost always possible to perpetuate and purify it.

For more than 35 years, the Division of Cereal Crops and Diseases, U. S. Department of Agriculture, has been growing barley experimentally. Varieties have been tested for yield and quality, and to determine their characteristics and behavior. Thousands of hybrids have been made, and their progenies grown and selected for better economic types as well as to determine the mode of inheritance of barley characters. It is but natural that on the basis of this long experience, procedures and techniques should be fairly well standardized. A description of some of them may be found useful to students, and to plant breeders who have not heretofore worked with cereals. While the barley plant is used as a basis, it is believed that the methods described may be used with slight modifications with other small grains. Many of the procedures described are elementary, merely following good greenhouse practice, or are customarily used by experienced cereal workers in many countries. Credit is due especially to other workers in the Division of Cereal Crops and Diseases, as their suggestions and criticisms have been freely used.

Growing the Crop

Field culture has the advantage over use of a greenhouse in that space limitations are not so exigent. Breeding small grains requires relatively little ground and choice plots can be selected. However, excessive heat, wind, and precipitation are likely to be encountered in many sections of the country which may be detrimental to the making of hybrids and to the best growth of hybrid seeds, especially of the weaker progeny. In some localities, disease problems are encountered which militate against success. Irrigated stations in dry areas such as those at Sacaton, Arizona, and Aberdeen, Idaho, are almost ideal. In any



ANCIENT BARLEY

Figure 2

The two spikes from an excavation in Egypt are about 2,000 years old. The kernels below are from Anatolian excavations at the site of Alishar, and belong to the Phrygian period (1200-700 B.C.)

DEVELOPMENT OF LATERAL FLORETS

Figure 3

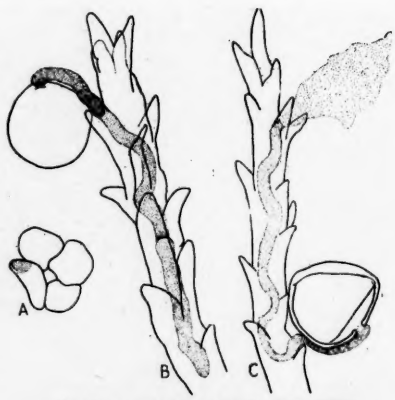
These four pairs of spikes and separated spikelets show the range of development of the lateral florets in four species of barley. *A* is a spike and spikelet of *Hordeum vulgare,* with the lateral florets fully fertile. In *H. intermedium* (*B*) the lateral florets are awnless and reduced in size: they may be either fertile or infertile. *C* shows the infertile lateral florets of *H. distichon.* In some varieties the laterals bear anthers having viable pollen. In *H. deficiens* (*D*) the lateral florets are vestigial. A primary classification of barley, as two-rowed or six-rowed, depends on the condition of the lateral florets. When these are fully fertile, the spike has six rows. When only the central floret is fertile, the spike has two rows.

case, the large population of later generations must be grown in the field and the final products must stand the test of field culture, taking their chances with the varied environments encountered in different parts of the country.

Greenhouse culture is subject to serious limitations of cost and space, but its advantages are many. Plants can be segregated and moved at will, small seeds and tender plants can be given special attention; the time of heading and flowering can be partly controlled; greenhouse climate is controllable within limits; winter and spring forms can be made to flower together, and of course the fertility of the growing medium can be fully controlled. In working with a disease problem, greenhouse culture usually affords better opportunities for

critical results because of the possibilities of controlling the environment.

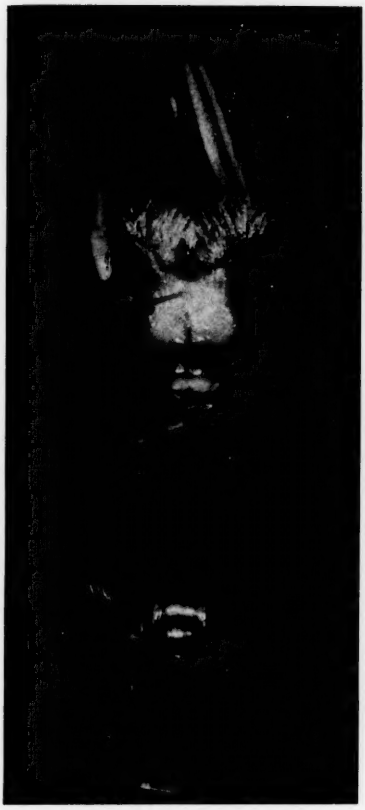
In growing barley, it is well to keep in mind that, in the field, low temperatures and short photo-periods favor vegetative growth, rising temperatures and lengthening photo-periods stimulate seed production, and high temperatures greatly accelerate the growth of the caryopsis. Winter barleys planted in the fall have their cold requirement satisfied by the winter temperatures. They grow rapidly and mature seed quickly in the spring as the days grow warmer and longer. Spring barleys sown in the spring grow good root systems and tiller freely in the low temperatures and relatively short days before jointing starts. As the temperature rises and the days lengthen, heading is stimulated and normal plants and yield may be expected. To obtain equally good results under glass, these conditions must be simulated. Within limits, desired modifications of habit, rate of growth, yield, etc., can be obtained by manipulating the environmental conditions. The cold requirement of sorts that are partly winter in habit, can often be satisfied by keeping the greenhouse temperatures low during the early stages of growth, or by planting the nursery very early in the spring. Such varieties will then flower along with the spring barleys. Extreme winter sorts can be fall planted in the field, and transplanted into the greenhouse in late December. A controlled method is the so-called "vernalization" or "iarovization" process, wherein the moistened seed of the winter varieties is subjected to a temperature of 33° to 40° F., for 30 to 45 days, depending on the variety. When these vernalized seeds are planted with spring sorts, winter and spring varieties may be brought into flower at about the same time. Early planting in the greenhouse (i.e., October to early November) makes it possible to keep the night temperatures down to 50°-55° F. In the day time, 60° is specified, but on most sunny days the figure is exceeded and this is not detrimental. Under these conditions, good rooting and tillering is obtained and flowering occurs in about four months, the two-rowed barleys in general being seven to ten days later than the six-rowed forms.* If sowing is delayed until December or January, the time to flowering is shortened, but the plants are likely to be poorer and to yield less with a shorter period of blooming. Then, too, it is harder to get good pollen in April or May than it is in February. Also, the high spring tempera-



STIGMA HAIRS AND POLLEN
Figure 4

Section (*A*) and side view (*B-C*) of barley stigma hairs, × 500. The cells are arranged around a central lumen to form a tube down which the germinating pollen grows. A cross-section of the stigma hair is shown at *A*, one of the cells being depicted with a nucleus. The germinating pollen sends out a tube which grows into the junction between two of the stigma hair cells and thence down to the ovary (as shown at *B*). Occasionally, upon entering the stigma hair, the pollen tube twists around and grows the wrong way, bursting as it emerges from near the tip of the stigma hair (*C*).

*Manchuria seed planted in the greenhouse at the Bureau of Plant Industry Station, Beltsville, Maryland, on September 24, 1942, produced tall, strong, well-tillered plants, which began heading on December 31. The first emasculations were made on January 4, 1943. It may be that this unusually rapid development was due to the possibility that the fall days, although shortening, were still potent in stimulating sexual development. The awns of Hannchen (two-rowed) barley planted on the same date did not emerge until February 4.



LOCATION OF FLOWER ON THE SPIKE
Figure 5

This enlarged photograph shows the structure of the barley spike with the flowers, which faced the other way, removed from the lower node. Successive flowers on opposite sides of the spike make up its reduplicated zig-zag structure.

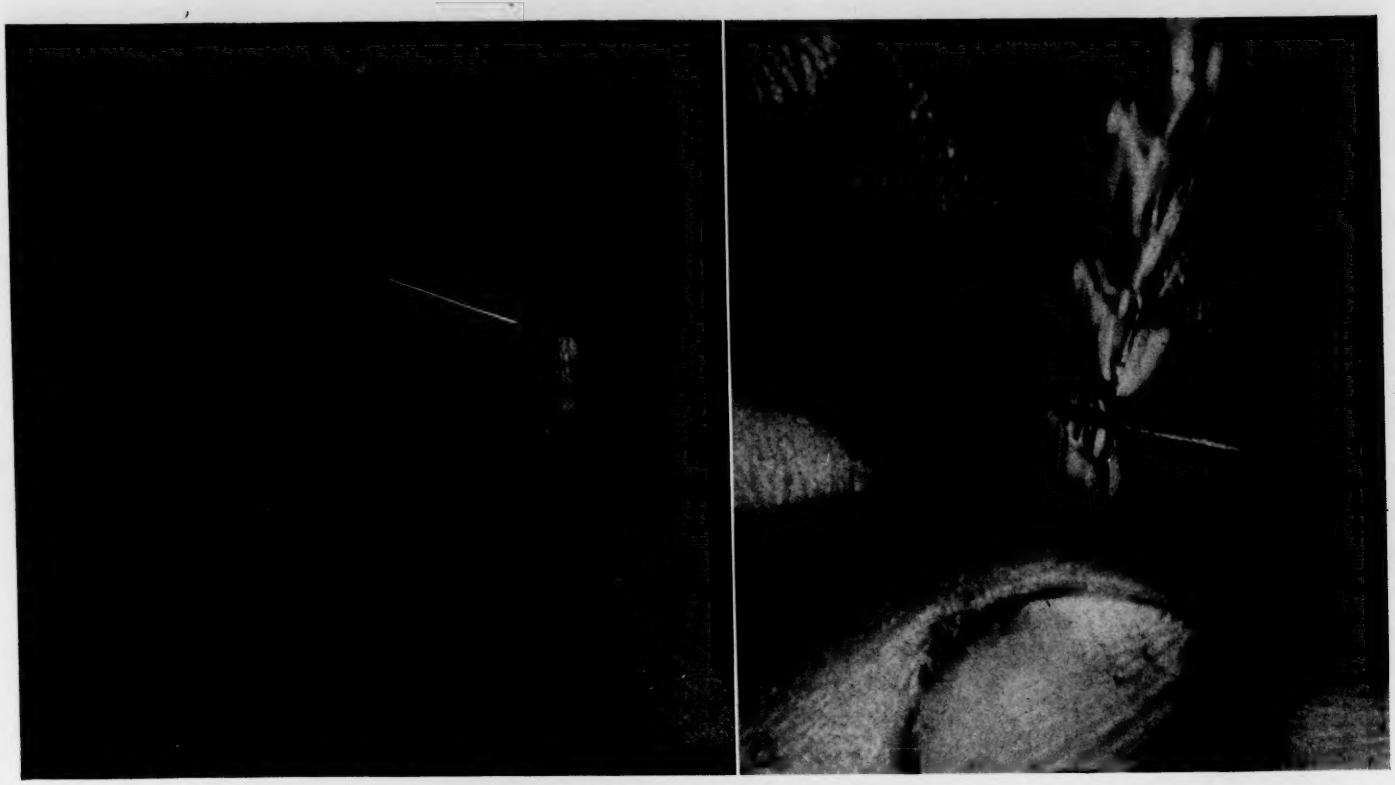
tures in the greenhouse may result in such rapid growth that the peduncles are soft and easily broken in handling the spike.

Development may be hastened about a month by increasing the "day length" by means of supplementary lights. However, this results in a shortened period of flowering, especially in winter varieties. Good results have been obtainable with 100-watt Mazda bulbs suspended about two feet above the plants, using a light for each 16 to 25 square feet of bench space. The lights are turned on at 5 p.m. and off at 11 p.m. In order to allow good initial vegetative growth, artificial illumination is not begun until jointing starts. Conversely, spring sorts can be retarded in growth, and their flowering period lengthened by planting early enough to take advantage of the shorter photoperiod of winter. Some sort of plant support is generally necessary in the greenhouse and often advantageous in the field. The device described by Taylor and Coffman[11] is simple, cheap and time-saving. The plants shown in Figure 9 are supported by this means.

Emasculation and Pollination

The single-flowered spikelets of barley are borne in opposite and alternating groups of three at the nodes of the rachis. The middle spikelet at the node is the largest and the laterals range in different species from fully fertile to vestigial. The four species of cultivated barley are shown in Figure 3. The flower is enclosed within the bract-like glumes and consists of an outer lemma, an inner palet, the lodicules, the ovule with its two-branched stigma, and three anthers on the ends of the slender stalks or filaments. The latter originate at the base of the ovule and are capable of great elongation (Figures 1 and 5). The anthers are attached below their middles so as to be top-heavy.

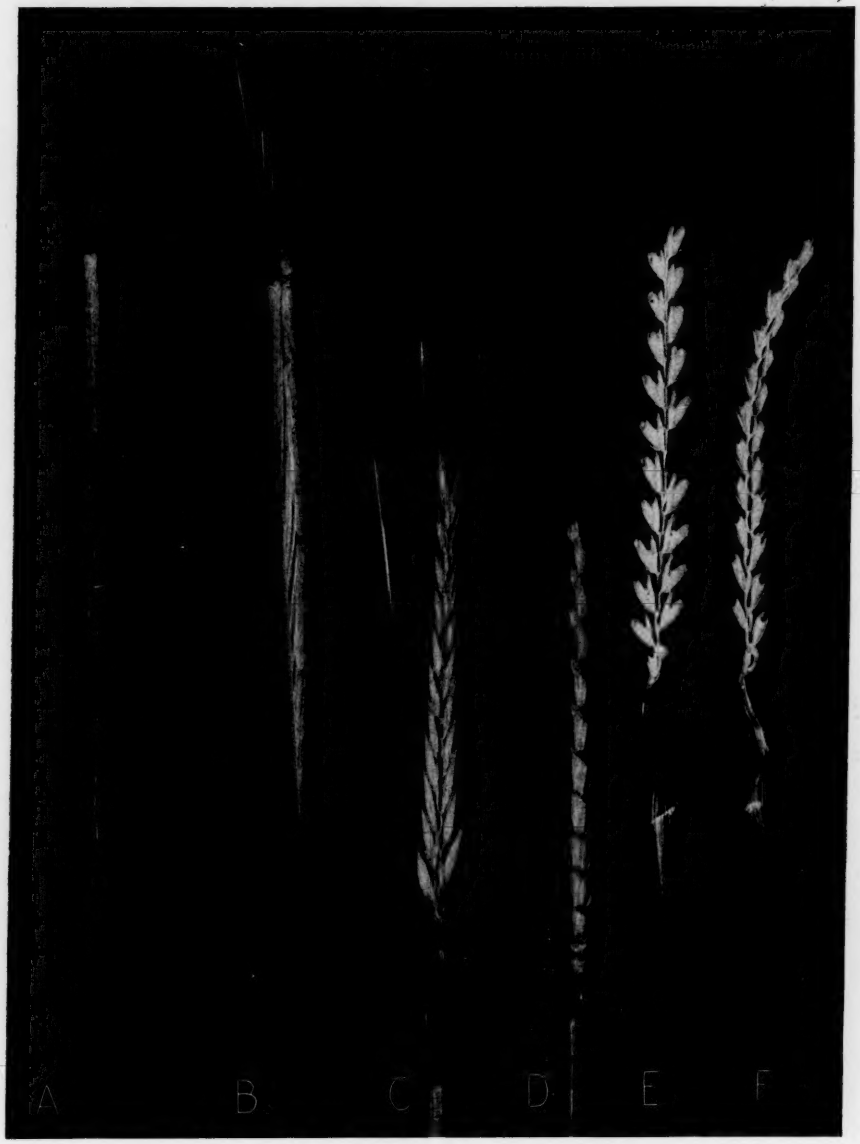
Barley is normally self-pollinated, like wheat, oats, and rice. Usually, the anthers dehisce before the spike emerges from the boot leaf and often without the flower's actually opening. The degree of spike emergence at flowering time varies with the environment. In the field, pollination is often practically completed before the tip of the spike appears. Occasionally, in the greenhouse it is delayed until the spike is entirely out of the boot leaf, in which event the lemma and palet are sprung apart by the swelling lodicules at the base of the ovule. The anthers emerge from the flower as the filaments elongate rapidly in a warming and drying atmosphere, and their



TECHNIQUE OF EMASCULATING BARLEY FLOWERS

Figure 6

These two photographs show the details of removing the anthers from a barley flower, preparatory to cross pollination. *A* shows a general view of the operator's hands and the spike being manipulated. *B* shows the details of the procedure three times natural size. The three anthers are benig removed in one operation with a fine-pointed weak-springed forceps. If the anthers are removed before they have opened, no pollen will be shed; the stigmas will be receptive to foreign pollen a day or so later.



PREPARATION OF BARLEY FLOWERS FOR CROSS POLLINATION

Figure 7

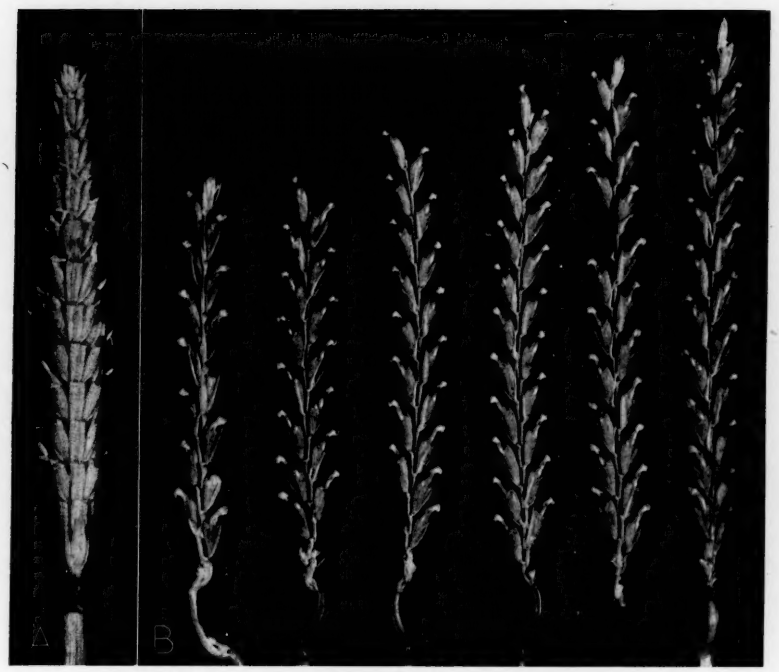
A shows the boot leaf of a barley plant with the spike enclosed, but too young for emasculation, in comparison with *B* wherein the expanding spike has separated the edges of the boot leaf so that the spike is beginning to be visible. *C* shows the boot leaf clipped off and lateral, basal, and tip flowers removed. *D*, the tips of lemmas and palets has been clipped off with a slanting cut just above the tips of the anthers. At this stage the anthers are removed (see Figure 6). *E* shows an emasculated barley spike with all the flowers open, and at the right stage to be pollinated. Occasionally the bursting of an anther at emasculation results in a selfed flower which remains closed and is removed at this time. *F* shows a barley spike hand-pollinated on the previous day. The flowers have closed again. The absence of any open flowers augurs well for a perfect set of seed. If the temperatures are low, the flowers remain open after pollination for a longer period.

lobes split at the distal end. Finally they tip over, spilling the dry powdery pollen upon the wide-spreading, feathery stigma. Flowering begins in the middle row of flowers, generally about two-thirds the way up the spike, and proceeds in both directions. The lateral flowers bloom still later, the flowering of an entire spike taking several days.

The pollen effective in fertilization is usually that which falls upon the tiny branches of the stigma. Each of these branches consists of four rows of elongated cells around a central lumen (Figure 4*A*). The distal end of each cell projects outward over the base of the cell just above. The pollen grain falling on the stigma hair, sticks to it and germinates within five minutes (at 70°-80° F.), sending out from its single pore a pollen tube. This grows in a meandering course until it comes in contact with the stigma hair. It then penetrates into the lumen by entering between the end of adjoining cells at the angle formed by the base of one cell and the projecting tip of the one just below. The entering tube is thus automatically directed proximally and continues its growth toward the ovule through the lumen of the stigma hair (Figure 4*B*). It seems doubtful if there is any attraction from the egg sac, influencing the direction of growth of the pollen tube at this stage, for pollen tubes have been observed that turned distally inside the stigma hair. They grew just as rapidly in the wrong direction, out of the end of the hair and then burst (Figure 4*C*). The rate of growth of the pollen tube through the stigma and ovule varies with the temperature.[10] At 80° F., male nuclei have been observed in the egg sac 20 minutes after pollination, while at 41° F., 140 minutes were required. Similarly, fertilization of the egg and polar nuclei, and growth of the caryopsis are retarded by low temperatures. At about 75° F., the fusion nucleus is in prophase in about six hours, and the embryo is making its first division 13 to 14 hours after the pollen was received on the stigma.[7] Therefore, at this temperature the proper time to irradiate the spike for the production of polyploids would be 14 to 16 hours after pollination.

Emasculation

Spikes selected for emasculation should be well developed, with the flowers swelling and the tissues beginning to harden. A spike with soft, easily-torn lemmas is a poor risk. If the operation is delayed until shortly before blooming, the spike can better withstand the necessary mutilation and exposure. However, in long-continued hot weather, the pollen ripens at earlier and earlier stages in the development of the spike, making it difficult to find spikes that will not be injured during emasculation.[5] The anthers should be plump and light green to yellowish in color. This stage usually is found when the spike is still in the boot, but can fairly well be judged by the length of awn or spike emergence, and by the increased diameter of the boot and spread of its edges due to the swelling of the spike (Figure 7*B*). Ordinarily, the boot leaf is then stripped from the head and cut off at the level of the first node of the rachis. If conditions indicate that protection from drying is necessary, the boot leaf may be merely removed from the spike and later re-rolled around it after emasculation. Since the lateral flowers of two-rowed barleys often bear viable pollen, they are stripped off the spike, and the basal and tip florets of the middle row are removed so that all the flowers left on the spike may open and their stigmas become receptive at the same time (Figure 7*C*). Next, the lemma and palet are clipped off with dissecting scissors at a level just above the anther tips, as described by Biffin.[2] A slanting cut with the lower end toward the operator facilitates the removal of the anthers (Figure 7*D*). This method has proved very successful. It is simple and rapid and, because the anthers are exposed, they can be removed without injury to the stigma. The method has the further advantage that such clipped flowers open widely and their stigmas extrude, making bulk pollinations by dusting very effective. (With rice flowers, the cut is at an angle in



SPIKE IN FLOWER, AND DEVELOPING SEEDS

Figure 8

A shows a barley spike with extended anthers. The upper third of lemmas and palets was clipped off before the anther filaments had elongated. These anthers were mature and emerged in a few minutes in the relatively dry warm air of the photographic laboratory. These are in ideal condition to dust over a cone containing emasculated spikes shown in Figure 8. *B* shows the seed-set obtained on the six spikes pollinated in the cone in Figure 9*A*. Spikes with fewer than 50 emerged anthers were shaken in the cone and more than 100 seeds were obtained.

the plane of the lemma-palet axis, so that about one-third of the lemma and little or none of the palet is removed). The three anthers are then removed (usually in one operation) with a pair of fine-pointed, weak-springed dissecting forceps (Figures 6*A* and 6*B*). With aging eyes, a Beebe binocular loupe or a watchmaker's eye lens is a great help. The foregoing treatment reduces the volume of the spike, and a glassine bag an inch or less in width and long enough (about 7 or 8 inches) to support the emasculated spike, is slipped down over the culm. In the greenhouse, no tying is necessary. If glassine bags are not available, the spike may be wrapped in ordinary tissue paper and tied. The culm should be labeled with a string tag bearing the identification and data. Bonnet[3] has found that the mutilation of the spike by this procedure results in smaller seeds and recommends that emasculation and hand pollination be accomplished through a longitudinal slit in the lemma of the unmutilated flower. However, this method is slower and less fool-proof, and the slight increase in seed size is of little practical importance.

To be successful, pollination must be done when the emasculated flowers are ready, and the pollen must be mature and fresh. Under field conditions in southeastern Idaho, Anthony and Harlan[1] obtained a seed set of 55 percent when the emasculated flowers were pol-

linated one day before their anthers would have dehisced naturally, 87 percent on the day of dehiscence, and a perfect seed set the day after natural dehiscence. The value then dropped rapidly to zero on the fifth day after natural dehiscence. Also, they emphasize the extremely delicate nature of barley pollen and state that pollen taken from anthers two to three hours before natural dehiscence or that remaining in anthers that had dehisced two to three hours previously was only about half as effective as that from fresh anthers.

The proper stage for pollination of emasculated spikes is evidenced by a wide separation of lemma and palet produced by the swollen lodicules, which separation (Figure 7*E*) allows the feathery stigma branches to protrude from the flower. Flower opening in the field will occur one to three days after emasculation, cool temperatures retarding the process.[5] The stigma may remain receptive for relatively long periods if kept cool.[8] Any closed flower found between widely open ones should be removed on the suspicion that it is selfed.

The customary method for hand-pollinating barley has been to invert a dehiscing anther into the individual flower. This operation is so slow as to limit greatly the number of spikes that can be pollinated. A much more rapid method, and one found to be as effective, is to slip a paper cone over the emasculated spike and shake inside it a spike of the pollen parent that has dehiscing anthers. Spikes with extruded anthers withered and hanging limp should not be used, as any pollen remaining in them is likely to have low viability. If several spikes are to be pollinated with the same pollen parent, as many as six or eight can be pollinated in the cone at once (Figure 9) by grouping the plants closely and bringing the spikes to the same level by slipping empty pots under the low ones. The seeds resulting from cone pollination of one spike each from the six plants shown in Figure 9*A* are shown in Figure 8*B*. The use of a different pollen parent for the next pollination necessitates a fresh cone as many of the pollen grains stick to the inside surface. The use of cone pollination greatly facilitates backcrossing.

In case the spikes do not show natural emergence of the anthers, one may follow the suggestion of Biffin[2] and cut off likely heads, rapidly clip off the distal thirds of the lemmas and support them upright in the sun. If there is good pollen in any of them, a rather rapid extrusion of the anthers from the head may be expected (Figure 8*A*). The writer has never been very successful in causing the anthers to extrude by the method used by Florell with wheat, of stroking the spike.[4] Usually, pollen is more abundant early in the morning as the sun is warming up the plants and the relative humidity is decreasing. In the greenhouse, opening the ventilators also encourages anthesis. Good pollen is harder to get as noon approaches, but usually can be obtained in limited quantities throughout the day. After pollination, the name or number of the pollen parent and the date, and any other information desired is written on the tag. The following day, unless the intervening temperatures have been low, a rough check can be made on seed set by inspecting the pollinated spike. The fertilized flowers will be closed (Figure 7*F*).

Timing Tricks

In case the parents do not flower at the same time, 3-node culms bearing emasculated flowers can be removed from the plant, their cut ends placed in distilled or tap water and stored in a refrigerator at 36° F. for as long as 42 days.[8] These may be pollinated when the anthers of the pollen parents are dehiscing. If the flasks containing the pollinated spikes are then placed in the greenhouse, or if the weather is suitable, out of doors, viable seeds should develop before the culms lose their chlorophyl. (The cold storage of pollen spikes is also feasible, although viable pollen is scarce after a week or so.) This seemingly drastic treatment may result in seeds but one-fourth to one-third the weight of well developed normal seeds, but such seeds are capable of germinating and

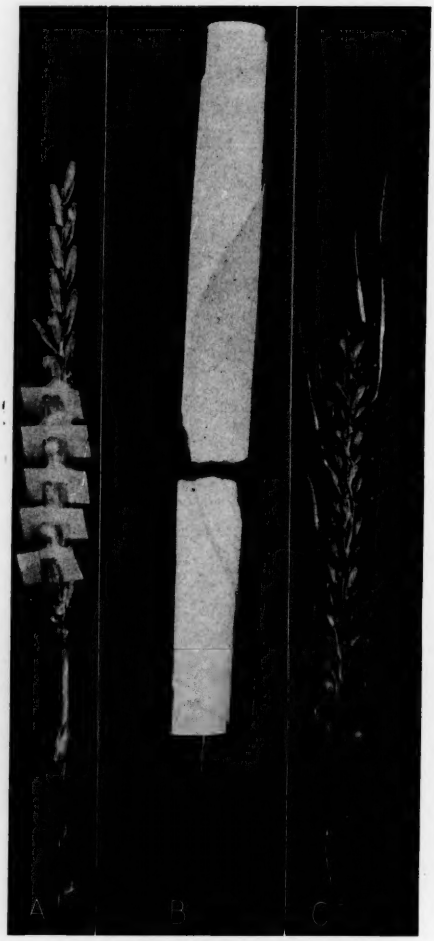
POLLINATION AND QUICK GERMINATION TECHNIQUES
Figure 9

A shows the cone method of pollination. Emasculated spikes from each of six barley plants have been brought to the same level and all six spikes are enclosed in a cone of rather stiff paper. These are now ready to be pollinated by a single male plant. At the left is a pot of soil supporting a number of prospective pollen spikes with clipped lemmas. One of these is shown in detail in Figure 8*A*. *B* shows the arrangement used in growing viviparous barley seedlings. The two plants at the left bear treated spikes (see Figure 10), and the flask contains a culm bearing an excised treated spike. All three of these spikes are wrapped together, covered with a sheet of glassine paper, and tied to the rod for support. They are kept wet by water dripping from the inverted flask above (see Figure 10).

producing normal plants. In fact, seeds harvested as early as five days after pollination and dried in the spike have germinated and grown to productive maturity.[6] However, they need special attention. It is wise to germinate undersized seeds on wet filter paper in a Petri dish and transplant the seedlings with the plumules exposed to the light; or, poorly developed seeds may be planted in greenhouse flats one-fourth inches deep and covered with finely sifted soil, sand or peat. If small or valuable seeds are to be grown within a few months after harvest, it is best to make sure that they have finished the after-ripening process. This may be determined easily by tagging at pollinating time a few unemasculated spikes of about the same age, harvesting them with the experimental crop.

When a test shows that the seed from the unemasculated spikes germinates well, it is safe to plant the experimental samples. Recently harvested seeds germinate better at 50° F., or lower, rather than at higher temperatures.

Should one wish materially to shorten the time necessary to grow the first generation, the crossed seeds can be made to germinate in the spike of the growing mother plant by keeping the embryo wet.[9] Early production of such seedlings is favored by temperature of 80°-86° F., growth and development is very much slower at 70° F. and lower. Seeds for such treatment should have grown slightly beyond the clipped tips of the lemma and palet which, at 80° to 85° F., requires six to eight days from pollination. The most feasible method of laying bare the embryo surface is to make (with a needle) two longitudinal slits, about 2-2½ mm. apart, in the face of the lemma, near the tip of the kernel, and then with the forceps, to pull this loosened flap down and twist it off without disturbing the kernel underneath. Rectangular strips of filter paper are then slipped down between the kernels, and to insure good contact a wad of wet filter paper pulp the size of a grain of wheat is inserted between the strip and the embryo. Different steps in the process are shown in Figure 10*A*. Here the lowest kernel holds the filter paper over the embryo of the first seed so treated; the next five kernels on one side are treated. The next seed is exposed and the loosened lemma flap is ready to be torn off. It is best to lay bare all the embryos first, then to insert all the strips and follow with the wads of pulp. The pulp wets the filter paper strips so that they stay in place well while the spike is rolled in a circle of filter paper and tied (Figure 10*B*). As many treated spikes as convenient can be wrapped in a larger piece of filter paper, topped by a wad of wet cotton and wrapped in glassine paper, and supported by tying loosely to an upright stake. The spikes are kept wet by pouring water on the cotton wad several times a day, or by a constant drip supplied as shown in Figure 9*B*. It



PRODUCTION OF VIVIPAROUS SEEDLINGS
Figure 10

When the seeds are six to eight days old they may be prepared for immediate germination by the techniques here shown. The seeds are exposed by loosening and removing a strip of the lemma as is shown here (*A*) on the seventh seed from the base. Then a rectangular strip of filter paper is slipped down between the seed and the seed below it. *B*, the entire spike thus treated is wrapped in filter paper and tied. *C*, this shows the result of keeping a spike thus prepared wet for about a week. Seven of the seeds have evidently germinated and actually 15 of the 19 treated seeds on this spike are ready to be transplanted.

is possible to economize space by cutting off the culm and allowing it to grow in a flask of water (Figure 9*B*) In the spring of 1943, two such culms produced 31 seedlings from 33 seeds. Since the seeds are well started when they are treated, there is little or no reduction in size from normal. A head containing viviparous seedlings is shown in Figure 10*C*. There are seven clearly evident in the photograph, and 15 of the 19 treated seeds were found to have germinated. By this method, seedlings produced 15 days after pollination have produced normal plants when transplanted. The method may be used with later generations, but the size of the population is limited by the labor involved.

Time Involved

A record has been kept of the time required for certain of the operations described. The task of emasculating 18 to 20 flowers on a spike of barley requires about four minutes. However, none but the most patient will wish to keep at the job all day long, and time is consumed in other operations such as finding suitable spikes, duplicating emasculations to replace damaged spikes, and in moving plants. The emasculation of 50 spikes of barley is a fair day's work, but this number may be increased if material is plentiful and one's nerves do not get ragged. Since barley pollen is extremely sensitive to drying, free pollen cannot be used advantageously, and the usual method of upsetting an anther into the flower takes about double the time necessary for emasculation. The process of picking off and emptying single anthers into individual flowers is, to the writer, exasperatingly tedious, hence the cone method. With a little practice, a spike may be treated and wrapped for the production of viviparous seedlings in about ten minutes.

To many, the slow painstaking tasks associated with the making of a hybrid and the care necessary in growing its first two generations are boresome, but considering the vast amount of mental and physical labor involved in growing the 11 to 13 subsequent generations usually required to produce a new variety, it is well worth while to avail oneself of all the known refinements of technique. And barley breeding has paid dividends. In 1935, 12,858,000 acres, of the crop valued at $111,271,000, were grown in the United States. Harlan and Martini, in the 1936 Yearbook of the U. S. Department of Agriculture, have listed 60 "superior" varieties. Some of these are old sorts which have been superceded by better ones and some are new varieties just coming into their own. Ten of the number are old introductions which have found a favorable environment, and are still grown on some 3,400,000 acres. Thirty are the products of plant breeding by State and Federal workers. Of these, 19 are selections from old or new introductions and are grown on over 5¼ million acres. The remaining 11 are hybrid selections, and account for four million acres. These 30 are grown because they yield more, are more resistant to disease, or have valuable characteristics, such as smooth awns or stiff straw, which the grower prefers, while retaining the high yield and quality of the better parent. A few more bushels per acre, less chance for crop failure, and greater comfort in handling the crop are a few of the attainments which will continue to pay dividends to the grower. We may hope for greater accomplishments in the future.

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A PEDIGREE OF SACRO-ILIAC ARTHRITIS

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ARTHRITIS is one of the commonest and most aggravating diseases, afflicting a great many species of lower animals as well as man. Symptomatically it is a disorder of the joints, exhibiting a wide variety of clinical forms and usually resulting in a great deal of distress and often incapacitation. Evidences of the effects of what is believed to have been arthritis have been observed in the bones of the small Triassic dinosaurs of several hundred million years ago.[7] Fox,[11] in an analysis of 1,749 skeletons and autopsies of wild animals ranging from anthropoid apes to deer, found 77 instances of arthritic changes that were accepted as genuine. In these animals the condition was best seen as an involvement of the spinal cord, although the appendicular skeleton was also extensively affected, the changes observed being similar to those found in the rheumatoid arthritides in man.

Willis[26] examined 1,559 human skeletons and found 86 that showed evidence of sacro-iliac arthritis. These exhibited ankylosis in one or both sacro-iliac joints, resulting from smooth calcification of the anterior sacro-iliac ligament or from irregular bone lipping at the periphy of the joint. The calcification involved part of the spinal column but not the skeleton in general, whereas the lipping was accompanied by arthritic changes throughout the skeleton. Histological examination of the hyaline cartilage of sacro-iliac joints from persons afflicted with sacro-iliac disorder showed surface fibrosis, myxomatous degeneration of the matrix and calcification.[22] Three factors believed operative in the etiology of these are age, mechanical strain and focal infection, all of which are thought to result in circulatory disturbances with alteration of calcium metabolism. Bastos and Mazo,[1] as well as other investigators, have shown that the blood serum of persons with ankylosed polyarthritis, non-articular arthritis deformans and progressive non-ankylosed polyarthritis deformans has a higher and more variable calcium content than that of individuals who have clinically recovered from the disease. For post-infectious secondary arthritis without deforming bone lesions, the calcium content was found to be more variable than in the control group but the mean value was the same.

Since the parathyroid is concerned with calcium metabolism it was thought that arthritic changes might be associated with hyperparathyroidism. Fifty-five polyarthritic patients were subjected to an operation involving removal of part of the parathyroid gland.[18] Out of 49 cases studied, 33 showed clinical improvement and 16 showed no change. Lack of improvement may have been due either to the fact that bone changes already formed might not be corrected or to the possibility that, since the parathyroids are difficult to identify, the operation failed to remove enough or any of these bodies. There is also evidence that hypo- or hypersecretion of either the thyroid or the pituitary may produce joint manifestation.[21] Recent experiments involving the overdosage of rats with the hormone of the adrenal cortex suggest that this gland may also play an important part in the etiology of rheumatic and rheumatoid conditions in man.[20]

Classification of Arthritis

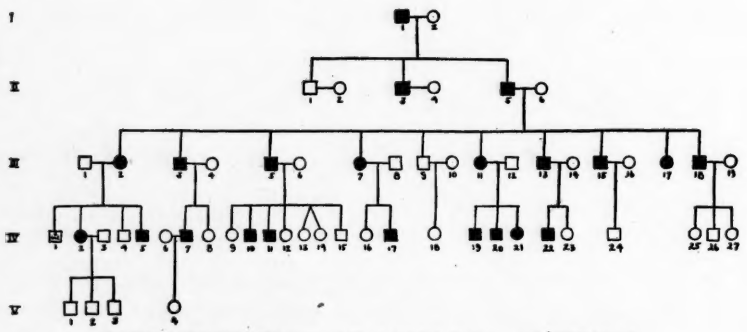
The most common forms of arthritis may be classified in the following general categories:[7] (a) infectious forms; (b) forms of unproven etiology, but probably infectious, (the latter group includes the arthritis of rheumatic fever, now pretty well established as the result of infection, with a recessive gene as a predisposing factor[20,27]), and rheumatoid arthritis, probably a chron-

ic infectious disease); (c) forms resulting from injury to the joint; (d) degenerative forms of joint disease; (e) gouty arthritis. The role of heredity is most pronounced in rheumatic fever and in the last two groups. For most of the infectious forms the influence of heredity is more difficult to ascertain. These are chiefly the result of infection by any one of a number of species of bacteria, some of which have been identified in humans as well as in rats and other animals suffering from arthritis. For example a pneumonia-like organism has been isolated in rats with polyarthritis. Mice can also be infected with this organism but monkeys, guinea pigs, rabbits, hedgehogs and moles could not be.[10] This strain is identical in morphology, filtrability, virulence, heat resistance, oxygen stability at 4° and 37° C. with a strain isolated from rats that had been inoculated with material from a person suffering from rheumatic fever.[2] Jarlov and Brinch,[17] working with rabbits and using streptococcus strains of low, medium and high virulence, were able to produce both acute and chronic joint diseases similar to those observed in man. Changes in the soft parts and bony tissue of the joints were observed and the marrow of the bone showed evidence of chronic inflammation, resulting in fibrous degeneration. Involvement of internal organs was relatively slight. On the other hand nonarthriotropic strains of streptococci did not show any tendency to produce lesions localized in the joints. Rothbard[19] produced acute multiple arthritis in 45 out of 51 albino rats injected with a group A hemolytic streptococcus strain obtained from a person with septicemia. In some cases the joints subsequently healed, in others the disease persisted eight or more weeks after inoculation. According to Cecil and Angevine[4] only 11 out of 100 rabbits became arthritic when injected by other than the intravenous route and in all of the 11 bacteria were recovered from the blood stream. It has been shown[5] that in over 60 per cent of the cases of arthritis deformans in man streptococci are present in the blood stream, and that when these are injected into rabbits most of the animals develop chronic non-suppurative arthritis.

Causes of Joint Pathology

The causes of the changes in the joints in arthritis are still incompletely understood. In some cases direct bacterial action is probable; in others toxins from an infected focus or bacterial allergens may initiate the changes that result in arthritis. In the arthritis of gout a disturbance of purine metabolism is generally believed to be the basic cause. Most patients with gout show evidence of damage to the kidneys; if the damage is not severe 90 per cent of the urates that filter through the glomeruli are reabsorbed by the tubules, resulting in an increase of uric acid in the blood and a decrease in the urine. With severe damage, tubule reabsorption is greatly diminished and the urates are cleared through the urine.[8,12] According to Chini[6] either uric acid or an allergen may induce increased activity of the histiocytic tissue of the joints, resulting in arthritis. Thus the chronic course of gout has been attributed by some to periods of renal destruction and regeneration,[12] while others believe the renal changes are the result and not the cause of the metabolic disorder.[8] Regarding the existence of a relationship between arthritis and allergy, opinion is conflicting, many denying any connection whatsoever. However, it appears possible the two may be in some way associated, at least with respect to some forms of arthritis.

In a statistical study of allergy and arthritis, Traut and Vrtiak[25] concluded that hypersensivity to various infections or to climatic changes is one of the possible causes of rheumatic diseases. They found that the incidence of asthma, hay fever, urticaria, eczema, rhinitis and migraine among 359 persons with various types of rheumatic diseases as well as among their relatives was much greater than in the case



FOUR GENERATIONS OF SACRO-ILIAC ARTHRITIS

Figure 11

The presence of twenty-two affected individuals in four generations suggests that sacro-iliac pain associated with other symptoms is dependent on a dominant hereditary factor.

of 100 persons suffering from non-rheumatic diseases. Persons with osteoarthritis exhibited allergic manifestations to a greater extent than did persons with rheumatic heart disease, while those with atrophic arthritis showed the lowest incidence of allergy. Ehrstrom[9] has found that alterations in the blood vessels in persons with diffuse glomerulo-nephritis, periarteritis nodosa and rheumatic arthritis may be allergic in nature, bacterial products being considered the antigens. According to Bruun[3] changes comparable with those found in rheumatic diseases in man can be produced in experimental animals by treatment with sterile, species-foreign horse serum. He considers that rheumatic fever and most forms of chronic polyarthritis are the result of bacterial influence in an organism altered by allergy.

Genetic Factors

In the case of the arthritis of gout, as is shown by studies of its incidence within a family, heredity may be regarded as one of the fundamental causes. Talbott[24] made a study of 138 relatives of 27 patients with gouty arthritis. Of these 138, none of whom showed symptoms or X-ray evidence of gout, the serum urate was normal in 102 with an average concentration of 4.6, while in 36 the concentration averaged 7.3. It appears likely that the hereditary disorder of purine metabolism may or may not manifest itself in symptoms of gouty arthritis, depending upon circumstances of which we are not certain, although excessive intake of purines appears to be one of the most probable. Most important from the standpoint of heredity are the various forms of osteoarthritis. These may appear either early or late in life and usually several members of a family are affected. In fact evidence of familial distribution may be said to be one of the diagnostic criteria. Inasmuch as removal of foci of infection has no influence on the course of these degenerative joint diseases they are no longer held to be primarily infectious in origin.[7] Herrman[14] has published 13 pedigrees of degenerative arthritis, of which seven show dominant heredity. In four of these seven the disease is present for two generations and in three it is transmitted through three. In three of the remaining pedigrees only collaterals were affected and in three no affected near relatives were found. Hangartner[13] has published a pedigree which shows 26 cases of chronic arthritis among 76 persons in five generations, and Holsti and Huuskonen[16] have described a family with 12 arth-

ritics out of 33 persons in three generations. Heberden's nodes, a hypertrophic arthritis of the finger joints, regarded by some investigators as a clinical entity, is strongly influenced by the action of genes. Stecher[21] studied 68 families in which this condition was present. He found that mothers of affected persons have the same disease with twice the frequency and sisters with three times the frequency as persons in the general population.

An Arthritic Family

Figure 11 shows a pedigree of a form of arthritis that has been present in a family in western New York State for at least four generations. All of the affected persons suffer pain in the sacro-iliac region; some also have sciatic pains and tingling and swelling of the extremities, conditions which are likely due to the pressure of hypertrophic tissue in the lumbosacral region.[15] Data for this study were collected by personal interview with affected and unaffected members of the pedigree, most of whom are still living. The pedigree shows 22 affected persons in four generations, with a ratio of 21 arthritics to 12 normal from siblings old enough to have developed the disease. The evidence therefore points to dominant inheritance with high penetrance. Following is a description of the symptoms in each of the affected individuals.

According to testimony of his family, I-1 complained of back trouble in the latter years of his life, although he does not appear to have been very seriously handicapped by it. He suffered from Bright's disease and died at 51, the cause being given as dropsy. His wife (I-2) showed no symptoms of arthritis. Of their three children the eldest (II-1) never complained of any illness or organic disturbance. The second (II-3) died of Bright's disease at the age of 70. Throughout life he complained of a back ailment that often kept him from work but seldom confined him to bed. He was 5'4" tall and weighed 200 pounds, indicating decided obesity. The third son (II-5) is still alive at the age of 77. He has suffered a back ailment since his early twenties. He has worked as a carpenter until the past two years and has often been laid up for days at a time because of the arthritic pains. He experiences violent attacks about twice yearly, suffering a constant minor aggravation in the lower part of the back the rest of the time. Each severe attack is accompanied by kidney trouble, sometimes causing blood in the urine. During his lifetime he has also suffered hardening of the arteries and in later years angina. His height is 5'9" and weight 135 lbs. His wife showed no symptoms of arthritis or kidney trouble.

The Third Generation

II-5 had ten children, of whom the first (III-2) has had definite symptoms of the disease since the age of 16. The pain centers in the sacro-iliac region and always extends down the backs of both legs. Sometimes it seems to follow up the spine to the region of the neck. It is always accompanied by severe tingling in all the extremities and her hands often become extremely swollen. Severe attacks may last for two weeks. Urinalysis has revealed an excess of uric acid. Her back ailment has been attributed to a kidney condition by two doctors and she has suffered from a bladder ailment since 17. She had rheumatic fever about 35 years ago and lately had undulent fever. Her height is 5'4" and weight 180 lbs. She has given birth to four children, the first of which was premature, dying at birth. The second child (IV-2) has suffered from pains in the sacro-iliac region since the age of 13 and also has a kidney ailment. The condition never confines her but it does prevent her from doing much lifting of any sort. Her age is 28, her height 5'8" and weight 170 lbs. She has three boys, aged 8, 7, and 3, all too young to show any symptoms. The next child (IV-4) at 25 shows no signs of the family disorder, but the fourth (IV-5) has experienced pains in the sacro-iliac re-

gion since the age of 12. He is 18 years old, 6'2" tall and weighs 170 lbs.

The second oldest person in the third generation (III-3) has at times been troubled with his back but the pains have not been as severe as in other of his relatives. Like many of the others he is somewhat obese, weighing 190 lbs. with a height of 5'7". His daughter, age 20, shows no symptoms, but a son (IV-7) suffers pains in the immediate region of the sacro-iliac which never confine him but limit his capacity for lifting. He is 24, weighs 150 lbs. and is 5'10" tall.

The next person in the third generation (III-5) has had a chronic back ailment since the middle teens that seems to have been precipitated by lifting the end of a log. The arthritic pains in the sacro-iliac region extend into the legs and sometimes into the upper part of the back and may confine him to bed for as much as two weeks at a time. Often throughout the year he suffers from back trouble but not of sufficient severity to incapacitate him. He is 50 years old, 5'10" tall and weighs 150 lbs. He has seven children, of whom the second and third (IV-10, 11), aged 21 and 19, are afflicted in about the same way as the father and have about the same physical characteristics. The other children exhibit none of the symptoms.

The fourth person of the third generation (III-7), aged 47, height 5'1" and weight 180 lbs., has suffered very painful attacks since the age of 13. The symptoms are much the same as for the others, confining her to bed for about three weeks out of every year. The pain centers in the sacro-iliac region and extends into the legs, making it impossible for her to stand straight. Even when not incapacitated she suffers frequent painful attacks. All of these are accompanied by a swelling and tingling in the hands and feet and an itching in all parts of the body. The first attack she had came on slowly but succeeding ones have been precipitated by less and less provocation. Diathermy and strapping have not alleviated the condition. Her oldest child (IV-16), at the age of 23, shows none of the symptoms, but the youngest (IV-17), aged 15, has had periodic recurrences of a dull pain in the sacro-iliac region for the past two years.

The fifth member of the pedigree in the third generation (III-8) has no symptoms of arthritis. His daughter, aged 16, likewise exhibits no symptoms.

The sixth member (III-11), aged 44, height 5'11" and weight 146 lbs., cannot remember the exact time of onset of arthritis but it was probably in her late teens. Her symptoms include pain in the sacro-iliac region and legs, tingling and swelling of the hands and feet and a very excruciating itching of the face and nose. The latter has been attributed by some doctors to an allergy but this is without confirmation. X-rays have revealed no bone deformation. She has three children. The first (IV-19), aged 22, height 5'8" and weight 185 lbs., has had symptoms since the age of 14. He simply found it impossible one morning to get out of bed. Further attacks appeared as a result of slight straining or from sudden or jerky movements of the legs or body. The pain seems to center in the sacro-iliac region but extends into the legs, making walking impossible. During extreme attacks it is comfortable to stay in one position for only very short periods and the greatest relief is obtained by sitting upright in a straight back chair. Violent attacks occur once or twice a year; at other times there is usually some slight pain in the lower back region. Attacks generally last about a week and the only successful means of alleviating the pain is to sleep on a hard straight surface such as the floor or a mattress with boards underneath. There is some slight tingling in the extremities but it is not bothersome. Diathermy and massage have both proved ineffective. X-rays reveal no bone deformation. The second child (IV-20), aged 18, height 5'8" and weight 145 lbs., has about the same symptoms as his broth-

er. With no apparent provocation he finds it impossible to arise from bed because of severe pains in the sacral region and upper parts of the legs. Otherwise he is in excellent health. At the age of 3½ he suffered a severe attack of nephritis which nearly ended in death. The youngest child (IV-21), aged 16, height 5'1½" and weight 110 lbs., has not yet been afflicted severely but at times complains of a localized backache.

The next member of the pedigree in the third generation (III-13) suffers from chronic back trouble which is always confined to the sacral region and is quite painful. The onset was around the twentieth year of life. Urinalysis revealed an excess of uric acid. The age of this person is 44, height 5'8" and weight 210 lbs. He has two children, a male, aged 20, who suffers to about the same extent as the father, and a female, aged 15, who shows no symptoms.

Individual III-15, aged 39, height 5'10", weight 200 lbs., first noticed symptoms during his late teens while doing heavy lifting. He is able to keep a job involving a lot of manual labor but is often forced to lay off work because of pains in the lower part of the back. He has a boy, aged 13, who shows no symptoms.

Individual III-17, aged 35, eight 5'3", weight 140 lbs., often has severe pains in the sacro-iliac region and extending into the right leg. She is confined to bed about three times yearly and suffers minor aggravation throughout the year. The condition had its onset in her middle twenties when she strained her back while training to be a nurse. The outside of the right leg and foot as well as all of the toes of the right foot become numb during an attack. There is also a twitching of the muscles of the leg and sometimes stiffness. The attacks are almost always accompanied by a burning sensation in the skin, tingling of the extremities and swelling of the hands and feet.

The youngest member of the third generation (III-18) is 32 years old, 5'7½" tall and weighs 153 lbs. The first symptoms of the disease appeared at the age of 18 while he was driving a tractor on a golf course. He is incapacitated about once yearly for a period of three weeks and continually wears a support for his back, without which he could not work. The pain is in the same region as in other members of the family, extending down the legs to the feet and accompanied by itching and tingling sensations. It usually appears during damp weather and is best alleviated by sleeping on a hard surface. He finds it difficult to breathe during severe attacks and becomes nervous and grouchy. He is married and has three children, all under ten and as yet with no symptoms of arthritis.

Conclusion

It will be seen from the above account that the condition is met for the most part either in persons who are somewhat obese or who do work of a manual nature. It would appear that the strain imposed by the weight or the exertion from lifting is one of the immediate factors in the onset of the pains. The presence of excess uric acid in the urine as well as the symptoms of kidney ailment suggest renal defects but it is impossible to say what these are or to decide whether they are basic causes or merely symptoms. It is possible the basic action of the gene is to influence purine metabolism and the renal disorder is secondary to this. If this is the case the disease in this family is more closely allied to the arthritis of gout than to any other form of arthritis. It is clear from the similarity of the symptoms in the afflicted members of the family that the disease is a genetic entity and that inheritance is most probably dominant in nature.

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AN EMBRYOLOGIST LOOKS AT ADULTS

A DISTINGUISHED experimental embryologist grapples in this book* with the problems of being a global citizen in the 1940's. The book comprises eleven essays and addresses written in the fateful interval 1935-1941. The opening chapter, "Metamorphosis of Scepticism" (actually the last to be written), thus outlines Needham's own spiritual and social embryology:

It is essential, therefore, to view all the forms of human experience in a social context. But I was profoundly sceptical of the right of any one of the forms of experience to have the last word about the world in which we live. Today I feel more confirmed in this scepticism than ever. A concentration on scientific experience alone gives you the individualistic researcher, inapt for team-work and bent on priority, the easy prey of all the reactionary social forms tending to make scientists the passive instruments of class domination.

In looking around one's colleagues it has been consistently evident that those with the narrowest specialist interests tend to be politically the most reactionary. Without history, the scientist will know nothing of social evolution, of the origin and progress of human society, of the laws of change and of the direction in which further progress is likely to take place. Without philosophy he can have no basic world-view, and may fall into all kinds of fantasies—for successful scientific work is compatible with anything from Roman Catholicism, as in the case of Pasteur, to Sandemanism as in the case of Faraday. It would be presumptuous in the case of such men to think that their scientific work would have been better if they had had better philosophies, but the majority of scientists are not of their calibre, and for these it is surely true that the better their philosophy the better their scientific work is likely to be. Without religion, the scientist will know little of comradeship with the mass of men, he will remain isolated from them in intellectual pride, and incapable of the humility which made Huxley give of his best to working-class audiences in "Mechanics' Institutes" or Timiriazev and Sechenov lecture illegally to Russian working men. Only by recognizing where the numinous really lies will he be able to take his part in the great Labour movement. As for the absence of aesthetic appreciation, one need not describe the kind of person he will be without that. All the forms of experience are necessary and no one of them has the last word. * * *

The consideration of man and his experiences as an individual lead in the end to contemplation; the consideration of social man

*NEEDHAM, JOSEPH: *Time, the Refreshing River.* Cambridge University Press, 1943.

and his experiences leads to action. No more shall we take Gautama and Plato for our guide, but rather those determined men who from Confucius to Marx were vehicles of the evolutionary process, working through them to implement the promise occluded in the very beginning of our world.

The second essay finds in Henry Drummond ("Natural Law in the Spiritual World," 1833), a prophet born before his time. "Why should evolution stop with the organic?" asked Drummond, a point of view which Needham feels is urgently needed at this time when the evolution of those "super-organisms," man's social and political structures, appears to be at a critical point. We must understand that the development of social structures is part of the evolutionary process; and that it is stupid and worse than futile to ignore this fact or to pretend that it is otherwise. He is convinced that the Hegelian concept of dialectical materialism best fills the ideological bill. The principle of emergent evolution comes in for repeated discussion. When an emergent system of higher complexity is set up, then the "laws" and the interactions which control a simpler system do not apply. The failure to grasp this obvious fact is the basis for such unrealistically dangerous and reactionary verbalism as using ant-societies as a text for preachments about human societies in bland indifference to the utter unlikeness of the organisms who build the two systems. Unfortunately, some biologists still manage to trap themselves, along with the unwary bystanders, by such tortured parables. For a breathtaking example of this futile and potentially dangerous pastime see "Parables for Peacemakers" in the April 1944 *Scientific Monthly*.

Needham holds that there is only one kind of science, be it theoretical or applied—that the yen to *know* can never be separated from the urge to make life safer or easier, human motives being as mixed as they are. Yet surely the difficulties Needham finds mankind heir to are in large part due to a partial acceptance of science. We are inclined to be quite "scientific" when a motor car goes wrong; some of us may even submit ourselves to a rigid factual analysis of the state of our heart or lungs (though many still flee even from an honest fact-finding in these areas). The advertiser can be scientific in determining the sales-response to a radio program, but the leaders of a democratic country can rarely persuade themselves to be equally objective. It is the exception to pay more than lip-service to the scientific method when our relations with others are involved. The terminology may be that of the factualistic Jacob, but the reactivity is that of the old Esau of incantation and magic. Needham is not fooled, but some who read his book might get the misapprehension that we live in an approximately scientific culture; actually we live in a gadgeteering technology, a very different thing.

That this is so is partly because few scientists are scientific outside the laboratory. As each day increasingly underlines the tragic shortcomings of a culture thus at war with itself, the need becomes greater to see the whole pageant of human progress as a natural process rather than as a mystical hocus-pocus. All this talk of "World Orders" and the frantic warnings that our species must organize on a "global basis" to avoid disaster are futile without a revolutionary change in outlook. Before the larger "super-organisms" can come into being the *cell unit of human society*, the individual, in immediate contact with other human beings, must somehow do a considerable metamorphosis. Science is not magic, and Needham may expect too great a change were we suddenly to become suffused with "dialetic materialism." We urgently need changes which help us to apply to mankind's everyday affairs the same objective reliance on experimental techniques that have been so successful in giving us control over the rest of nature. Should our "reorganized" society symbolize merely new magic in place of the old, the changes will be useless, or worse. Needham believes that periods of "idealism" have been periods of social retrogression, because when people hitch their wagons to un- or other-worldly stars the realities are lost

sight of. To get down to fundamental brass tacks in re-channeling the outlook of our society so that we may freely apply a scientific viewpoint of problems of his species is perhaps the most compelling challenge to man's inventive genius that has ever been faced. We must abandon the magic of words and of wish-thinking in our everyday lives as completely as it has been abandoned in the transmutation of metals, or in the treatment of smallpox and diphtheria.

We cannot wait smugly for "all the data to be in and analyzed" as some of the ivory-tower brethren insist. Radio waves and the jet propelled bombers and fighters of year after next travel much too fast for us to risk such retreats. Until we are honestly willing to analyze and understand the stress-generating factors in our culture, we can never correct them. Even granting considerable hocus-pocus in the findings of the Freudian and other psychologists, enough has been solidly established to leave no doubt that the conflict between what man *is* and what he must must *pretend to be* results in a tragic social schizophrenia. This pathetic ideational procrustisizing serves no useful purpose. We pity the Ubangis because they torture their lips into duck-bills. The duck-billing of the personality is the greater tragedy, and it is still found throughout the genus *Homo*.

The emergent that the world is waiting for, and which must be achieved before a super-state can be more than more weight on the safety-valve, is the re-orientation and re-integration which is possible when we honestly look at human beings with humor and scientific realism—not as make-believe. "I accept the universe," exclaimed the lady in the story. "Gad, she'd better," cracked Carlisle. In somewhat the same spirit man is going to have to accept himself. When he gets his supernatural and bogus-idiotional nonsense about himself knocked out of him, an evolutionary emergent of a world-society becomes possible: not before. Until that considerable miracle is achieved, there is no real hope of resolving the problems that confront us. Emergent evolution cannot transmute the sum of frustrations into their opposite. We emerge in directions we are travelling, and we cannot emerge into freedom and understanding by travelling in the direction of bound minds and pathological evasions.

From a number of viewpoints, Needham considers how the processes of science bear on the life of our day. The machine as a social instrument and as a lethal device for destroying human beings (in the factory as well as on the battelfield); the balance between observation-experiment and theory in advancing science; the futility of attempting to make sociology merely high-faluting primate biology; philosophy and science—these and many other matters are stimulatingly discussed. The apparent conflict between the second law of thermodynamics and evolution is considered at length. The one pictures the universe as "running down" while the other reveals biological processes cast in a pattern of increasing complexity. A resolution of this paradox is necessary because the second law of thermodynamics has been the basis for much impassioned pessimism. The principle of entropy or increasing "mixed-up-ness" has as its opposite "separatedness" rather than organization. To the entropist, a crystal is "mixed-up-ness," but it represents a step in the direction of biological organization in being a "patterned mixed-up-ness." "And the general up-shot would be that the world has been moving steadily from a condition of universal separatedness (order) to one of general chaotic mixed-up-ness (thermodynamic disorder) plus local organization (patterned mixed-up-ness)." Needham suggests that the more highly organized societies should be the least wasteful. "Hence it is significant that much of the criticism directed against our existing social order by those who would see a more highly organized state of society is precisely on the ground that our present arrangements are wasteful. Wasteful of human effort, when infinite care is devoted to the growing of a crop of coffee, only for it to be shoveled into locomotive fireboxes. Wasteful of ener-

gy, when heavy goods, the transport of which is not urgent, are transported by air or rail, while for purely financial reasons canals lie unused or derelict. Is there not a thermodynamic interpretation of justice? Is not injustice wasteful? Is not the failure to utilize to the maximum the available talent and genius of men a wasteful thing?" From the "order" of separatedness to the "locally patterned disorder" of increasing mixed-up-ness, Needham sees the operation of an evolutionary principle broad enough to include both intropy and the emergence of increasingly complex human societies.

The final essay discusses integrative levels. It was written in 1937, just as the Spanish Civil War raised the curtain on total war. Time scales are its theme, as they affect theologians, biologists, and Herbert Spencer—as protagonist of a point of view important at one stage of social evolution. This closes with some reflections on a strangely symbolic incident from Herbert Spencer's younger days, when railroads were less formal and more deliberate than they are today. Spencer, then an assistant engineer of the London and Birmingham railway, wanted to stop one night at a tiny way-station. He was inspired to attempt "hitchhiking" by rail on the London express, a procedure at least theoretically feasible before Westinghouse coupled trains with rubber hose to stop them. His baggage truck had no brake, and the idea was to uncouple it far enough in advance of the place where he wanted to stop so that it would coast in to a convenient siding. Unfortunately the future champion of evolution miscalculated and rolled several miles beyond his intended destination. He suffered several tense moments when he feared the venture would end fatally.

How Spencer had to seek help to clear the line and finally got home in the early hours of the morning, we need not here relate. But of all the symbolic occurrences which have happened to great men, this is surely one of the most remarkable. Spencer wanted to stop at the intermediate station in evolutionary sociology, but in the progress of organisation to ever higher levels, there is no such opportunity. The class of which he was the intellectual representative wanted to stop at the intermediate station of domestic capitalism, but the inner logic of the process demanded that expansion should go on and the local mill-owner should give place to the trustified imperialist. Moreover, the inevitable industrialisation of the working-class led to demands of diametrically opposite nature, so that Spencer was driven into the position of protesting vainly against both the "degeneration" into militarism, and the socialist movement which fought against "free competition." His wide, and substantially correct, survey of evolution lead up only to the anti-climax of middle-class liberal economic individualism, past which, in spite of himself, he was carried on protesting.

But let us celebrate his noble range of vision, nevertheless. The onward progress of integration and organization cannot be arrested. As I write, there rages in one of the most beautiful of European countries a tragic and terrible struggle between the People and their Adversary. The sound of its gunfire penetrates any College court, no matter how peaceful it may seem. Some faith may be needed to assert with boldness that, even if Spanish democracy be overwhelmed, even if the great democracy of the Soviet Union itself were to be overwhelmed, no matter what shattering blows the cause of consciousness may receive, the end is sure. The higher stages of integration and organization towards which we look have all the authority of evolution behind them. It is no other than Herbert Spencer himself who contributes to this our faith, if faith it be. The devil, as Hippolytus said long ago, may resist the cosmic process. But the last victory will not be his.

The book needs to be read by all who feel an urge to sound off on "world conditions." Do our plans apply to the level of integration at which we propose to use them? Have we an economic or an emotional vested interest in "the position in society in which the Lord placed us," or to which our early training conditioned us? In charting his own emergence as a free individual, Needham shows how hard it is to escape from the crysalis of the past. Yet this we must do, or we are indeed lost. We must profit from the past without being bound by it. "All the past is prologue"; but to the extinct species captured in the rocks, and to the extinct cultures embalmed in the amber of history, there is no time any more—and no future. Emerge or die, very likely is the alternative we face, and those who have the courage to struggle to "think ahead" into this great adventure will find this book a challenge and an inspiration.

—R. C.

GENETICS OF CULTIVATED CUCURBITS

C. F. POOLE*

SINCE Whitaker and Jagger's summary in 1937 of the genetic data then available on cucurbits,[19] a number of important additions to the literature have appeared. The present study is an effort to bring up to date our knowledge of the genetics of cucurbit crops from all available sources. It also includes data from some watermelon crosses made at Charleston, S. C., not elsewhere reported. In 1937 only half a dozen characters in watermelon had been investigated, whereas today the number has increased to 25 qualitative characters† determined by 15 pairs of alleles, a series of three alleles and 13 genes determining inheritance of fruit weight in one cross and backcross[12] sufficiently advanced for presentation. Recent genetic research has increased the number of cucumber characters to about 17, determined by about 15 pairs of alleles. But inclusion of no more than eight of these in any one coordinated study makes an accurate determination of the number of genes impossible. No new information will be included in this report unless it post-dates the information on genetics which appeared in the 1937 *Yearbook* of the U. S. Department of Agriculture.[19]

Watermelon

Citrullus Vulgaris

Table I presents a chronologically arranged list of 25 separate crosses involving as many qualitatively classified mendelian alleles in the watermelon. The list comprises approximately 15 distinct genes, seven of which (shown in Table II) are presumably situated on three chromosomes. Since the watermelon has eleven pairs of chromosomes, no doubt several of the eight genes from Table I not shown in Table II may eventually be shown to be linked rather than each to be resident on different ones of the remaining eight chromosomes. In addition to the seven linkages of Table II it is probable that the group *M* (mottled skin), *G* (dark green skin), and g^s (striped skin) includes at least one known gene for fruit weight; and also that the group *A* (sex), *O* (fruit shape), and probably *C* (a new yellow flesh color) also includes one known gene for fruit weight.

Partly as a result of the similarity in magnitude of crossover percentages between *M*-*G* (39.9 ± 4.3 per cent) and *M*-g^s (33.8 ± 4.6 per cent Weetman concluded that the *G*-*g* alleles (dark green skin *vs* light green skin) and g^s-*g* (striped skin *vs* self-colored skin) were triple alleles rather than two pairs of alleles. Weetman also observed that *M* was significantly correlated with fruit weight, that *O* (fruit shape) was significantly correlated with fruit weight, but that *M* and *O* failed to show a significant interaction. He therefore concluded that *M* and *O* were on different chromosomes and that these two weight genes were genetically different. This is not necessarily true, however.

At Charleston we have also found that *O* (fruit shape) is significantly correlated with weight in three out of four crosses studied, that *O* and *A* (sex) are linked, and that *A* shows a significant interaction with weight in some crosses but not in others.[12] This is interpreted to mean that *O* lies between the *A* and the weight loci involved, but that the distance between *A* and the weight locus is too great for a measurable interaction to be consistently observed in a limited number of observations.

Other reasons are presented in Table IV for placing *M* and *O* on different

*Cytologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, United States Department of Agriculture.

†See Literature references 5, 8, 11, 12, 13, 14, 18, 21. In addition the author presents new data regarding 16 characters in this article (see Table I).

chromosomes. Table IV shows the author's results of testing 12 genes, from the 15 already described, for chi-square linkage values in 36 out of 66 possible combinations. This table is divided by a diagonal line. Above this diagonal are given maximum chi-squares; below the diagonal are minimum chi-squares for studies in which more than one source of information is available. In cases where both triangles contain the same values only one cross involving that combination has been studied. The genes *G* and *O* show no significant linkage chi-square values in two different crosses, 3.093 and 0.154, where 5% probability for 1 degree of freedom is 3.841. The only genes from Table I not included are: *E* for explosiveness of rind,[13] *M* for Iowa Belle type of mottling of the skin,[18] and *P*, for a pencil stripe on the skin.[18]

Significant chi-square values are shown by asterisk, and since undisputed evidence of linkage requires that minimum chi-square values also must be significant, the only three cases of indicated linkage are those of *O—A* (shape-sex), *O—C* (shape—new canary-yellow flesh color), and *L—W* (long seed—one of the seed color genes). More crosses were investigated, but no linkage chi-square values were placed in this table unless both main gene chi-square values were non-significant.

Returning to Table I it will be observed that *RTW* and *D* determine coat colors or patterns. The seed coat color genes *RTW* form an interaction system[11] in which *RTW* is black, *RtW* is tan, *Rtw* is white tan-tipped, *rtW* is red, and *rtw* is white pink-tipped. The two phenotypes *rTW* and *rTw* have not been encountered at Charleston; but in view of McKay's report of tan × red, and green × red crosses[8] it is probable that *rTW* is green, because that is the only one of the eight phenotypes possible in this system which, when crossed with *rtW*, will give 3 green : 1 red in F_2. The allelic pair *D* vs *d* is apparently a modifier of the black seed phenotype only, wherein *RTWD* is flat or solid black, *RTWd* is dotted or stippled black.[11]

The gene pair *Cc*, canary-yellow *vs* pink, is reported here for the first time and is known from the cross canary-colored flesh × pink, the former from the recently popular commercial variety Honey Cream, the latter from Dove. Table IV shows that *C* segregates independently of the three seed color genes *D*, *T*, and *W*, but probably is linked with the fruit-shape gene *O*. This makes the fourth identified point on what is probably the linkage system *A-O-C* together with a weight gene. The point of chief interest is that canary-yellow is dominant over pink, whereas the golden-yellow flesh of Yellow Flesh Ice Cream and Golden Honey is recessive to red. Table IV shows that *Y* is independent of *A*, a member of the 4-point linkage system, but that *C* may be linked with *O* which is a member of that system. Therefore it is likely, although the evidence is not conclusively proven, that these two shades of yellow flesh are not alleles, but have different loci. They are therefore symbolized as *Y* for the golden-yellow locus and *C* for the canary yellow locus. The linkage chi-square value of *A-O* is 13.661 which is statistically highly significant for one degree of freedom; but evidence for this linkage (crossover value, 26.5 ± 8.2) is obtained from a single cross only and more evidence should be available before considering that 13.661 is not a chance estimate.

In many crosses investigated at this laboratory it has been impossible to obtain a non-significant chi-square value for the gene *E*, non-explosive *vs* explosive rind.[13] This may be due to the fact that degrees of explosiveness, according to Kenny and Porter,[6] are determined by differences in the time of day at which fruits are picked. The same authors show, however, that different watermelon varieties have significantly different thicknesses of rind cell walls. When fruits from four F_4 families of the cross Northern Sweet × Dove at Charleston, S. C., were classified for *E* vs *e* (by their reaction on insertion of a knife) and measured for cell wall resistance by pressure readings with a penetrometer, the non-explosive plants averaged 272.81 ± 6.5 gm. per sq. cm. and the explosives

averaged 236.5 ± 7.2 gm., a highly significant difference of 36.4 ± 9.7. Of the four F_4 families two have consistently thick-walled rind cells and two have thin-walled cells. It was further observed that explosive fruits from the two heavy-cell-walled families averaged 272.6 gm. pressure whereas non-explosive fruits of the two thin-cell-walled families averaged 150.9 gm. Therefore explosiveness and rind toughness are probably two entirely different characters, and it appears that the latter has a simple genetic basis.

The skin mottling of Iowa Belle is shown by Weetman[18] to have a mendelian basis showing a segregation of three self to one mottled in F_2. It is of interest to compare this with another type of mottling studied by the author and here first reported. This characterizes the variety Sun Moon and Stars, which has yellow dots over both leaves and fruits, and larger "suns" and "moons" over the fruits and sometimes the leaves as well. Studies of leaf mottling in five backcrosses and three F_2 populations may be summarized as follows: The character is due to a chloroplast deficiency situated in the cell cytoplasm, rather than controlled genetically through the cell nucleus. An occasional chloroplast may be carried by a fertilizing pollen tube and in this way instances of male transmission of deficient chloroplasts can be accounted for. F_2 and backcrosses to the variegated parent segregated variegated and non-variegated in approximately the same proportions found in the original crosses in which the female parent had been variegated. If the male backcross parent was non-variegated, the proportion of non-variegated segregants increased. If the female parent was non-variegated, or if a female non-variegated plant was used in a backcross, variegated segregants were found only very rarely.

In a cross between a long heavy-weight fruit (17.5 lbs.) and a round light-weight fruit (7.0 lbs.) it was estimated that 25 genes were segregating in F_2 and that 12 were segregating in the backcross to the light-weight parent, i.e., 12 to 13 loci were involved in this cross between two varieties where the heavier parent was heterozygous; therefore an odd number of genes segregated in F_2.

The most important plant breeding problem in watermelon concerns resistance to watermelon wilt [*Fusarium bulbigenum* (Cke. and Massee) var. *niveum* (E. F. Smith) Wr.]. An analysis of the author's data reveals a definite correlation between the percentages of survivors of F_3 and F_4 families. Several pairs of genes appear to be involved in an inheritance similar to that reported for cucumber mosaic virus.[19] Inheritance of resistance to anthracnose [*Colletotrichum lagenarium* (Pass.) Ell. and Hals] was found by Layton[18] to be controlled by a single pair of genes, in which resistant (*B*) is dominant over susceptible (*b*).

Cucumber

Cucumis sativus

Workers on the genetics of cucumber have described about 18 classifiable qualitative characters. These are listed in Table V with gene symbols designed to conform with the first eight proposed by Hutchins,[2] who studied some of the relationships among the eight genes listed in Table III. The linkage chi-square values of Table III were calculated from Hutchins' published data. Sixteen chi-square values out of a possible 28 combinations disclose but two significant values, and each of these is 12.037. This indicates* linkage in the repulsion phase with 16.3 ± 6.5 per cent crossing-over, between the genes *S* (spine number) and *C* (a flesh color gene), or between *F* (coarseness of spines) and *C*.

Not only are identical linkage chi-square values found for *S-C* and *F-C* (the only indicated cases of linkage) but also all five of the gene interactions involving *F* or *S* are identical. Therefore it seems likely that there is only one

*When solved by maximum likelihood method of Fisher, which is necessary because the double recessive class has less than 10 members.

gene for spine number (*S*) and spine coarseness (*F*), instead of the two proposed by Hutchins.[2] The cucumber shows a number of instances of close association of characters, interpreted by some workers to be complete linkage and by others to be either complete linkage or pleiotropic effects of a single gene (that is, one gene may have important influence in determining the expression of two or more characters). Perhaps a situation similar to that here suggested for *F* and *S* exists with regard to the following instances of complete linkage with no crossovers summarized by Hutchins:

1. Coarse spines, *F*, with few spines, *S*; fine spines, *f*, with numerous spines, *s*.
2. Black skins, *B*, with red and orange fruit, *RC*; white spines, *b*, with yellow and cream fruit, *rc*.
3. Black spines, *B*, with heavy netting, *H*; white spines, *b*, with no netting, *h*.
4. Heavy netting, *H*, with red and orange fruit, *RC*; no netting, *h*, with yellow and cream fruit, *rc*.
5. Determinate growth habit, *I*, with short plant, *t*, small number and yield of mature fruit, greater number of days to first female flower, and short and few laterals; indeterminate growth habit, *i*, with the opposites of the other characters.

Granting that in the foregoing five categories we have but four loci instead of seven (i.e., one for spine number and kind, two for spine and fruit color plus netting, and one for determinate habit plus height) then it is probable that the 18 phenotypes of Table V represent about 15 loci, among which is identified one measured linkage between *S* (spine number or quality and *C* (one of the two genes for flesh color).

Shifriss, Myers and Chupp[15] studied the inheritance of resistance to mosaic virus in cucumbers, their methods and findings are an important contribution to a better understanding of many hitherto baffling problems of disease-resistance in other cucurbits. When potted seedlings in a segregating population are inoculated with the virus, the susceptible plants show chlorosis in the cotyledons, but tolerant plants do not. The degree of tolerance is shown by the relative distance up the stem at which the first chlorotic leaf appears.

Statistical treatment of these data permitted a qualitative classification of the population, and disclosed that at different stages of development the ratios of resistant and susceptible plants were altered. These shifts were great enough to alter the mendelian ratios significantly. These alterations in ratios result from the operation, at different stages of growth, of several dominant gene modifiers of a basic genotype which comprises three pairs of complementary interacting alleles producing an F_2 ratio of *27* nonchlorotic : *37* chlorotic. Operation of these modifiers at different growth stages has the result that very few symptomless plants are observed if the entire growth span is considered.

Cochran[1] studied resistance to downy mildew, and although he offered no genetic analysis he found that in a cross between susceptible and resistant parents the F_1 generation was more resistant than either parent, and that among F_2 segregants some plants showed as much resistance as the resistant parent. Both Hutchins[3] and Tkachenko[17] report a single pair of alleles determining corolla color, called "yellow *vs* green" by the former and "yellowish orange *vs* light yellow" by the latter. In the absence of color chart readings we may assume that these two pairs of alleles are identical.

No attempt has been made to study the interaction effects of the 15 probable genes of Table V except the first seven reported by Hutchins. Consequently nothing can be said about linkage groups based on crossover percentages, with the exception of *S*-*C* already noted. Since *C. sativus* has only seven pairs of chromosomes, there are doubtless other undiscovered linkages among the genes listed in Table V.

Muskmelon

Cucumis melo

Critical genetic analysis with biotypes of *C. melo* before 1937 was practically confined to the two pairs of alleles described by Rosa,[14] viz, the sex genes *A* (monoecious, mostly staminate flowers but with some pistillate), dominant over *a* (andromonoecious, mostly staminate

but with some perfect flowers), and genes for carpel number, the three-carpellate ovary being determined by a dominant allele of the gene for five-carpellate ovary.

Poole and Grimball[10] obtained an hermaphrodite muskmelon from China, in which all the flowers were perfect. This was crossed with the sex types already described — monoecious and andromonoecious. Analysis of F_2 and backcross generations of the cross monoecious × hermaphrodite revealed that hermaphrodite is double recessive to monoecious, with the following indicated genes: *AG*, monoecious; *Ag*, gynomonoecious (mostly pistillate flowers, but some perfect); *aG*, andromonoecious; and *ag*,

TABLE I. Summary of genotypes, phenotypes and Mendelian ratios in *Citrullus vulgaris* reported from 25 distinct crosses involving 16 separate genes, listed in approximate chronological order of discovery. Numbers in parenthesis refer to literature cited, and an asterisk indicates that the genes were studied in the present investigations and that new data are reported here.

	Alleles	*Alternative Phenotypes and Ratios Obtained*	*Investigators*
1.	*A* vs *a*	3 Monoecious : 1 andromonoecious sex.	(12), (14)*
2.	*D* vs *d*	3 Solid black : 1 dotted black seed coat.	(5), (11)*
3.	*RtW* vs *rtW*	3 Tan seed coat : 1 red.	(8)
4.	*rTW* vs *rtW*†	3 Green seed coat : 1 red.	(8)
5.	*E* vs *e*	3 Non-explosive rind : 1 explosive.	(13)
6.	*Y* vs *y*	3 Red flesh : 1 yellow.	(13), (18)*
7.	*RTW vs RtW*	3 Black seed : 1 tan.	(11), (18)*
8.	*RtW* vs *Rtw*	3 Tan seed : 1 White tan-tipped.	(1), (3)*
9.	*G* vs *g*	3 Dark green skin : 1 light green.	(13), (18)*
10.	*G* vs g^s	3 Dark green skin : 1 striped.	(13), (18)
11.	g^s vs *g*	3 Striped skin : 1 non-striped.	(18)
12.	*M* vs *m*	3 Self-colored skin : 1 mottled (Iowa Belle).	(18)
13.	*P* vs *p*	3 Self-colored skin : 1 penciled lines on skin.	(18)
14.	*RTW* vs *RTw*	3 Black seed coat : 1 clump.	(18)*
15.	*RtW* vs *RTw*	Tan vs clump seed coat, 9 black : 3 tan : 3 clump : 1 white, tan tip.	(18)*
16.	*O* vs *o*	1 Elongate fruit : 2 intermediate : 1 spherical.	(12), (18)*
17.	*LS* vs *Ls*	3 Medium seed : 1 short.	(11)
18.	*LS* vs *ls*	3 Medium seed : 1 long.	(11)
19.	*Ls* vs *ls*	9 Short seed : 3 medium : 4 long.	(11)
20.	*RtW* × *rtw*	Tan vs white pink-tipped seed, 9 tan : 3 red : 3 white-tan tip : 1 white, pink tipped.	(11)*
21.	*RTW* × *Rtw*	Black vs white tan-tipped seed, 9 black : 3 clump : 3 tan : 1 white, tan-tipped.	(11)*
22.	*Rtw* × *RTw*	3 Clump seed : 1 white tan-tipped.	(11)*
23.	*C* vs *c*	3 Canary-yellow flesh : 1 pink flesh.	*
24.	*F* vs *f*	3 Smooth fruit surface : 1 furrowed.	*
25.	*B* vs *b*	3 Resistant (anthracnose) : 1 susceptible.	(7)

†Genotypes inferred from analysis reported by Poole et al.[11]

TABLE II. Seven cases of probable linkage in watermelon reported in certain of the investigations cited in Table I. Crossover percentages are shown for qualitative characters; correlation coefficients are shown where one of the phenotypes is a quantitative character not convertible.

	Genes	*Crossover percentages or correlation coefficients indicated*	*Investigators*
1.	*M* and *G*	39.9 ± 4.3 percent	(18)
	M and g^s	33.8 ± 4.6 percent	(18)
2.	*M* and fruit weight	r = .38 in F_2; r = .65 in backcross to lightweight parent.	(18)
3.	*A* and *O*	13.6 ± 2.9% in backcross; 20.7 ± 1.0% in F_3; 35.0 ± 3.5% in F_2.	(12)
4.	*C* and *O*	26.5 ± 8.2% in F_2.	*
5.	*O* and fruit weight	r = −.31 total variance; r = −.86 Mendelian phenotypes.	(12)
	Same	r = −.34 F_2 total variance; r = −.41 F_2 total variance.	(18)
6.	*A* and fruit weight	Linkage probable, but estimation impossible, difference between mean weight: A = 5.08 ± .24, *a* = 4.42 ± .22 kg.	(12)
7.	*L* and *W*	15.8 ± 1.2% in backcross, 19.3 ± 1.1% in coupling F_2, 21.5 ± 7.2% in F_3, 24.7 ± 4.9% in repulsion F_2.	(11)

hermaphrodite. Environmental effects made the gynomonoecious phenotype quite variable, producing some plants classed as gynoecious and trimonoecious; but the other three phenotypes were readily classified in their expected proportions in F_2 and backcross generations.

The foregoing sex habits are all asso-

TABLE III. Linkage chi-square values for 16 out of a possible 28 combinations for genes reported by Hutchins, calculated from his published data (9).

	F	B	S	I	H	R	C	T
F		.003	-	.345	.345	.003	12.037*	-
B			.003	.003	-	-	-	-
S				.345	.345	.003	12.037*	-
I					.140	.003	.003	.266
H						-	-	-
R							.003	-
C								-
T								

TABLE IV. Recent calculations of linkage chi-square values for 36 gene interactions among 12 of the 15 loci listed in Table I. Significant chi-square values are shown by asterisks. The upper right-hand half of the table gives maximum values. The other half of the table gives minimum values where more than one analysis was made. Data are all from studies made at U. S. Regional Vegetable Breeding Laboratory.

* Indicates a repulsion linkage, with 16.5 6.5 per cent crossingover, estimated by maximum likelihood.

Genes	A	D	L	R	S	T	W	O	G	Y	C	F
A		.048	.307	1.257	6.760*	2.355	2.061	36.460**	1.000	.002	---	---
D	.017		1.543	--	1.518	---	---	---	---	---	2.562	---
L	.021	0		3.141	ca.240	1.866	158.912**	---	---	1.094	---	0
R	1.257	---	3.141		2.935	---	.024	0	---	---	---	---
S	3.355	1.518	ca.240	---		.398	18.724**	---	---	.292	---	---
T	1.580	---	1.866	---	.062		7.567**	.978	1.033	---	.003	---
W	0	---	147.260**	---	.062	.364		.610	1.154	5.872*	.900	.367
O	34.282**	---	.006	0	---	.390	.006		3.093	---	13.661**	---
G	1.000	---	---	2.778	---	1.033	1.154	.154		---	---	---
Y	.002	---	.001	---	.292	---	.682	---	---		---	.241
C	---	2.562	---	---	---	.003	.900	13.661**	---	---		---
F	---	---	0	---	---	---	.367	---	---	.241	---	

TABLE V. Summary of genes, characters and Mendelian ratios in *Cucumis sativus* reported by 4 workers from 17 distinct crosses; the number of separate genes is uncertain for lack of co-ordinated study. Gene symbols for only the first 7 crosses were proposed by authors cited.

	Alleles	*Phenotypes, F_2, Ratios*	*Investigators*
1.	*F* vs *f*	3 Coarse spines on fruit : 1 fine.	(2)
2.	*B* vs *b*	3 Black spines : 1 white.	(1), (2), (17)
3.	*S* vs *s*	3 Few spines : 1 numerous.	(2)
4.	*I* vs *i*	3 Determinate growth habit : 1 indeterminate.	(2)
5.	*H* vs *h*	3 Heavy netting on fruit : 1 no netting.	(2)
6.	*RC* vs *rc*	9 Red fruit color : 3 orange (*Rc*) : 3 yellow (*rC*) : 1 cream (*rc*).	(2)
7.	*T* vs *t*	3 Tall plant height : 1 short.	(2)
8.	*W* vs *w*	3 Cream flesh color : 1 white.	(1), (16)
9.	*A* vs *a*	3 Spines : 1 no spines.	(16)
10.	*M* vs *m*	3 Mottled skin : 1 self-colored.	(16)
11.	*G* vs *g*	3 Dull skin : 1 glossy.	(16)
12.	*Te* vs *te*	3 Tough skin : 1 tender.	(16)
13.	*Tu* vs *tu*	3 Warty skin : 1 non-warty.	(16)
14.	*D* vs *d*	3 "Female" sex habit : 1 "male".	(17)
15.	*Y* vs *y*	3 Orange corolla : 1 yellow.	(3), (17)
16.	*V* vs *v*	3 Normal leaf discoloration : 1 virescent.	(17)
17.	*P* vs *p*	3 Smooth brown fruit surface : 1 rough yellow.	(17)

ciated with inferior ovaries, but Pangalo[9] found pistillate-flowered cucurbits with a superior ovary in the species *Cucumis chinensis* Pang. Discovery of phenotypes with superior ovaries increases the diversification of sex types from eight to an expected 16 (including dioecious, which Pangalo omitted).

A cross designed to give all 16 types was made between *C. chinensis* and *C. flexuosis* but has not progressed beyond an F_2 generation of 338 plants, which lacked some of the expected phenotypes. A genetic analysis of Pangalo's expected fifteen types will not be made until investigation of an F_3 generation, but Pangalo believes at least ten pairs of genes are involved.

Resistance to Race 1 of cantaloupe powdery mildew (*Erysiphe cichoracearum* DC) was reported by Jaggar and Scott[4] as due to a single dominant gene. Whitaker and Pryor[20] have developed a strain of cantaloupe resistant to both Races 1 and 2. Preliminary studies [20] substantiate the monogenic inheritance of resistance to Race 1 but have not progressed far enough for the authors to present a genetic interpretation of inheritance of resistance to Race 2.

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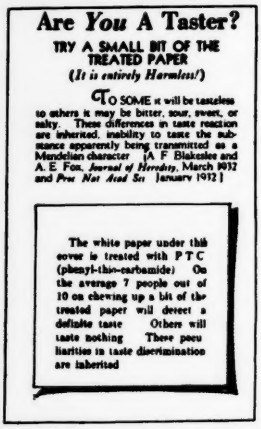
Amphidiploids of Wheat and Agropyron

Since 1930 the Russians have been experimenting with crosses between wheat and ryegrass and allied species. The purpose of these crosses has been to produce either "perennial wheat" or superior forage grasses. Neither objective seems to have been attained as yet. Two Canadian experimenters, John M. Armstrong and H. A. McLennan, report the results of chromosome doubling experiments with the relatively sterile wheat-ryegrass hybrids. (*Scientific Agriculture* 24:395-398.) Hybrids of six species of wheat with *A. glaucum* were used as the experimental material. Five methods of colchicine treatment were used: Treatment of dry seeds; treatment of germinated seeds; plumule immersion; germinated seed treated in partial vacuum. All of these methods produced some amphidiploids. The most productive procedures were the two vacuum treatments.

Thirteen hybrids, all involving *A. glaucum* and seven wheat varieties have been carried through the F_2. Four of these are in the F_4 or F_5 generations. Some of the hybrids are now being grown in quantity for testing.

Theoretically these should contain 70 chromosomes. Actually the full complement of chromosomes was not found in any of the hybrids studied cytologically. The total chromosome number ran from 56 to 69.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